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TEST SHIPMENTS OF PAPAYAS

WITH SPECIAL REFERENCE TO STORAGE DECAY CONTROL

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INTRODUCTION

A condition for the certification of fresh papayas shipped to the mainland United States, as set forth by the USDA Bureau of Entomology and Plant Quarantine, is that these fruits be either fumigated with EDB (ethylene dibromide) (*4*) or vapor-heat treated (*3*) to kill eggs and larvae of fruit flies. For the commercial shipper, the EDB method has many advantages over the older vapor-heat method. EDB requires only 2 hours treating time as compared to the 16–18 hours (8¾ hours plus conditioning time of 6–8 hours) time required for vapor heat. The EDB treating plant is less expensive to equip, maintain, and operate than is the vapor heat plant. Furthermore, the EDB treatment, so far as is known, has had no adverse effect on fruit quality, while the vapor-heat treatment has at times been known to considerably reduce fruit quality.

Shippers using the EDB method have found, however, that considerable percentages of EDB-treated papayas shipped from Hawaii to the West Coast decayed either during the transit period or soon after arrival on the market. Papayas shipped by the vapor-heat treatment were comparatively free from storage decay, and as a result they found wider market acceptance than the EDB-treated fruits.

It should be noted that fruits already infected with organisms, such as anthracnose, will decay in storage and that the EDB treatment itself neither promotes nor inhibits storage decay (*1*, *2*). Papayas from clean, well-sprayed orchards usually have less storage decay after the EDB treatment than those from unsprayed orchards. Also, papayas harvested during the winter months seem to have more storage decay than those harvested in the summer; a partial explanation is that, in winter, cool and rainy weather favor the build-up of certain decay organisms.

Because there is a large demand for papayas during the winter months, and because some shippers are equipped with only EDB treating chambers, Akamine and Arisumi (*1*, *2*) recommended the hot water treatment as a control measure for anthracnose, which is a major cause of storage decay in EDB-treated papayas. In a series of experiments carried out under simulated shipping conditions, they found that the development of this decay can be suppressed by immersing papayas in hot water at temperatures from 110° to 120° F. for 20 minutes. This treatment was equally effective in controlling storage decay when given either before or after the EDB treatment. Because the EDB treatment and the packing and storing operations immediately following fumigation are carried out under strict quarantine regulations, the authors recommended that papayas be treated with hot water before fumigation to economize on inspection time.

The hot water treatment did not affect the appearance or edible quality of the fruit. Hot water temperatures above 120° F. scalded the fruit surface even at short exposures. Various detergents and fungicidal dips were found to be relatively ineffective in controlling storage decay due to anthracnose. A probable explanation of this fact was suggested by these authors citing the work of Simmonds (*6*) who found that the infection hyphae of the decay organisms lay in a protected position beneath the cuticle of the epidermis of the fruit. Volatile chemicals such as 1,1,2-trichloroethane, S-tetrachloroethane, trichloroethylene, and tetrachloroethylene were found to cause fruit injury in the concentrations necessary to control anthracnose (*1*, *2*).

Shoji (*5*) in his storage studies of vapor-heat treated and EDB treated fruits found that the anthracnose development of ripe fruits was held at a minimum when the fruit was stored at 45° F., and at a maximum when stored at 65° F. or at room temperatures (70°–80° F.). He also pointed out that 65° F. was an ideal shipping temperature for mature green fruits; these fruits colored and ripened to the edible stage during a 7-day storage period, about the normal transit time from Honolulu to San Francisco by ocean freight. He also recommended shipping papayas at 55° F. in the summer, when West Coast temperatures do not differ much from temperatures in Hawaii, and then lower shipping temperatures for riper fruits during the winter when West Coast temperatures are lower than in Hawaii. Shoji also suggested that papayas shipped during the winter be ripened before shipment, and he pointed out that storing papayas at room temperatures before shipment is a practical method.

As most shippers were concerned with controlling storage decay and having papayas reach the mainland markets in an edible or nearly edible condition, test shipments from Hawaii to San Francisco were designed to test some of the treatments and methods recommended by Akamine and Arisumi (*1*, *2*) and Shoji (*5*) under actual shipping conditions.

EXPERIMENTAL PROCEDURE

Solo papayas (*Carica papaya* L.) were obtained from orchards known to have high incidence of anthracnose. Only mature green and color-turning Grade A papayas from a single source were selected for each test shipment. These fruits were supplied by a wholesaler one or two days before the scheduled shipping date, and they were prepared for shipment according to regulations set forth by the USDA Bureau of Entomology and Plant Quarantine, i.e., they were either EDB treated or vapor-heat treated and packed under the supervision of an authorized inspector.

Vapor-heat treatment for certification was done by a shipper at his treating plant. All other treatments of Oahu papayas, including the EDB treatment for certification, were carried out at the University's department of plant physiology. At the completion of the EDB or vapor-heat treatment, each fruit was wrapped in a tissue fruit wrap, then packed and sealed in a standard 10-pound papaya carton padded with excelsior or shredded paper. Eight to ten fruits were packed in each carton. The papayas packed in sealed cartons were either ripened at room temperatures or placed in cold storage until shipping time. Fruits used in the test shipment from Hilo were EDB treated at a commercial shipping plant in Hilo and stored at 45° F. until shipping time.

Treatments used in the test shipments were as follows:

1. *EDB method* (ethylene dibromide). Fruits were fumigated at a dosage of ½ pound per 1,000 cubic feet of chamber volume for 2 hours at a minimum fruit temperature of 70° F. This treatment fulfilled a requirement for the certification of papayas shipped to the Mainland. The control fruits in this study had no treatment except fumigation with EDB.
2. *Hot water method* (hereafter, HW). Fruits were immersed in hot water at 115° or 120° F. for 20 minutes. A 55-gallon drum filled with hot water was used to treat about 100 pounds of fruit at one time. The hot water temperature was maintained by regulating the direct flow of steam into the water bath; a steam hose was used for this purpose. The hot water treatment was followed by the EDB treatment to fulfill a certification requirement.
3. *Short vapor-heat method* (hereafter, SVH). This treatment should not be confused with the regular vapor-heat treatment required for certification. Fruits were conditioned with low relative humidity, 30–33 per cent, at a chamber temperature of 115° F. for 3 hours and then heated for an additional 2 hours at 115° F. under saturated conditions. Fruit temperatures at the end of the conditioning period averaged 109° F., and at the end of the treatment about 112°–114° F. This treatment was followed by the EDB treatment.
4. *Vapor-heat method* (hereafter, VH). The fruits were conditioned according to the plans of the shipper who treated these fruits. The conditioning period was followed by 8¾ hours of heating under saturated conditions at chamber temperatures high enough to maintain a minimum fruit temperature of 110° F. This treatment fulfilled a requirement for certification.
5. *Waxing method.* A fungicide, Dowicide A (Sodium-O-Phenylphenate), was added to two different brands of commercial fruit-and-vegetable waxes to make up a 2 percent emulsion. The fruits were dipped into this fungicide-wax mixture immediately after the EDB treatment and allowed to dry before packing. Johnson's "Primafresh" wax with Dowicide A will be referred to as Wax A and the Brog-Dex "Britex" wax with Dowicide A, as Wax B.

The test shipments were examined within a day after their arrival in San Francisco and stored for further observation at room temperatures (50°–60° F.) at Calavo (California Avocado Company), San Francisco. Each fruit was numbered, and individual fruit records of color development, ripening, and decay lesions were kept from the time of arrival up to the end of storage. Average daily fruit temperatures were determined from fruit thermometer readings of four fruits placed in different locations within the experimental pack.

The fruits were rated for ripeness and assigned numerical values:

(a) Mature green—0.
Mature fruits showing only green external color; flesh firm and hard.

(b) Color turning—0.
Mature fruits showing a tinge of yellow color; flesh firm and hard.

(c) ¼ ripe—.25.
Mature fruits showing more extensive development of yellow color than color-turning fruits, and just beginning to yield to pressure when pressed with the fingers.

(d) ½ ripe—.50.

(e) ¾ ripe—.75.
½ ripe and ¾ ripe are intermediate stages between ¼ ripe and ripe approximated by color development and degree of softness when pressure is applied with the fingers.

(f) ripe—1.
Maximum edible stage.

(g) post ripe—1.
Past the edible stage, characterized by off-flavor and breakdown of flesh.

Observations made for ripeness were checked periodically by cutting open sample fruits.

Fruits were rated for color and assigned numerical values:

(a) Zero color—0.
Fruits showing only green external color.

(b) Color turning—0.
Fruits showing a tinge of yellow external color.

(c) ¼ color—.25.
Fruits having approximately ¼ of the external surface broken by yellow color.

(d) ½ color—.50.
Fruits having approximately ½ of the external surface broken by yellow color.

(e) ¾ color—.75.
Fruits having approximately ¾ of the external surface broken by yellow color.

(f) Full color—1.00.
Fruits having more than ¾ of the external surface broken by yellow color.

The average percentages of color or ripeness were calculated by dividing the sum of these numerical values in a given lot by the total number of fruits.

The average proportion of fruits in each stage of ripeness was obtained by dividing the total number of observations for that stage of ripeness by the total number of observations, e.g., a sample of 50 fruits observed at 7 different intervals would generate a matrix containing 350 observations, and if 40 of these observations were of the ¼ ripe designation, then 40/350 would be the average proportion of fruits in this stage of ripeness. Average proportions were used in calculating the expected frequencies of decay for each stage of ripeness.

Treatments were compared on the percentages of fruits decayed per observational period, cumulative percentages of decay at each observational period, proportion of stem-end rots to side rots, and on the various stages of ripeness in which fruits decayed. Decay lesions on the basal portion of the fruit surface were classified as stem-end rots and those on other parts of the surface classified as side rots. The percentages decayed per observational period were calculated from the number of fruits decayed in a sample of clean fruits carried over from a previous observational period, e.g., a sample of 50 fruits having 10 decayed would yield a sample size of 40 fruits for the next observational period. Some bias toward higher percentages of decay in the controls was noted because of their rapidly diminishing sample sizes. These percentages were transformed to degrees for the analysis of variance.

RESULTS

Tables 1–5 show the percentages of fruits decayed in treatments used for the test shipments. In these tables, the first set of figures under "zero days after arrival" represents percentages decayed from the time of packing until arrival in San Francisco (1–2 days waiting period before shipment and 6–7 days transit period). The percentages of fruits decayed thereafter are listed in appropriate columns under "days after arrival." The averages given in these tables are based on the number of observational periods and have no reference to mean daily percentages.

TEST SHIPMENT 1

LOT 1

Description: Oahu papayas, mature green to color turning, harvested January 13, 1953. Treated and packed January 14. Stored at 45° F. for 36 hours before shipping. Shipped from Honolulu to San Francisco via *Hawaiian Farmer*, January 16. Shipping temperature, 50° F. Arrived in San Francisco, January 22. Average fruit temperature after arrival: morning, 54°–55° F.; afternoon, 59°–60° F. (See table 1a.)

LOT 2

Description: Same as Lot 1, except that these fruits came from another orchard on Oahu. (See table 1b.)

TEST SHIPMENT 2

Description: Oahu papayas, mature green to color turning, harvested January 20, 1953. Treated and packed January 21. Stored at 45° F. until

TABLE 1a. Effect of treatment on development of storage decay. (Expressed in percent of fruit decayed.)

TREATMENT	FRUITS IN SAMPLE	DAYS AFTER ARRIVAL								REMARKS
		0	2	4	6	8	10	12	Average	
HW 115° F./20 min.	50	0	2.0	8.2	11.1	25.0	0	13.3	8.5	all normal
SVH	50	0	8.0	4.3	15.9	21.6	6.9	0	8.1	18 heat-injured
Control	50	26.0	35.1	25.0	16.7	40.0	44.4	80.0	38.2	all normal

Required difference between treatment means: 5.2 for P=5%
10.0 for P=1%

shipping time. Shipped from Honolulu to San Francisco via *Hawaiian Pilot*, January 22. Shipping temperature, 47° F. Arrived in San Francisco, January 29. Average fruit temperatures under room temperature condition: 54°–55° F. during the morning and 59°–60° F. in the afternoon. (See table 2.)

TEST SHIPMENT 3

LOT 1

Description: Oahu papayas, mature green to color turning, harvested March 29, 1953. Treated and packed March 30. Stored in sealed cartons at room temperatures (70°–80° F.) for 24 hours before shipping. Shipped from Honolulu to San Francisco via *Hawaiian Builder* on March 31. Shipping temperatures, 44° F. and 55° F. Arrived in San Francisco, April 7. Average fruit temperatures after arrival: 50°–52° F. for the first seven days; for the last five days, 55° F. in the morning and 58° F. in the afternoon. (See table 3.)

LOT 2

These fruits came from the same source as Lot 1 of Shipment 3, but they differed in the harvesting date and mode of handling. Fruits were hot water treated the day after harvest and left at room temperatures (70°–80° F.) for two days while a comparable sample was being vapor-heat treated at a commercial treating plant. The hot water treated fruits were stored at 45° F. for three days, EDB treated, then packed and shipped on the same day as Lot 1 fruits. Although most of the fruits were ripe at the time of packing, they were

TABLE 1b. Effect of treatment on development of storage decay. (Expressed as percent of fruit decayed.)

TREATMENT	FRUITS IN SAMPLE	DAYS AFTER ARRIVAL								REMARKS
		0	2	4	6	8	10	12	Average	
HW 115° F./20 min.	50	0	2.0	4.1	8.5	34.9	10.7	20.0	11.4	all normal
Control	50	24.0	28.9	40.7	50.0	37.5	20.0	0	28.7	all normal

Mean difference not significant.

TABLE 2. Effect of treatment on development of storage decay. (Expressed as percent of fruit decayed.)

TREATMENT	FRUITS IN SAMPLE	DAYS AFTER ARRIVAL					REMARKS
		0	2	4	6	Average	
SVH	80	0	6.2	2.7	5.5	3.6	2 slightly heat-injured
HW 120° F./20 min.	79	0	8.9	6.9	7.5	5.8	all normal
Control	55	14.5	59.6	10.5	35.3	30.0	all normal

Required difference between treatment means: 4.0 for P=5%
9.0 for P=1%

shipped at 55° F. in order to have the same shipping temperature as the vapor-heat treated papayas.

The vapor-heat treated fruits were severely scalded from this treatment and were discarded shortly after arrival in San Francisco. The hot water treated fruits had cumulative percentages of decay of 5.3 per cent at arrival, 14.0 percent three days later, and 29.8 percent six days after arrival. (See table 3.)

TEST SHIPMENT 4

Description: Harvested May 4, 1953. Oahu papayas, mature green to color turning; treated and packed May 5. Left at room temperatures (70°–80° F.) for 24 hours. Shipped from Honolulu to San Francisco via *Hawaiian Farmer*, May 6 at 47° F. Arrived in San Francisco May 13. Average fruit temperature after arrival, 58°–60° F. (See table 4.)

TEST SHIPMENT 5

Description: Hilo papayas. Harvested in the color-turning stage, May 7, 1953. Treated and packed May 8 and stored at 44° F. until May 11 when

TABLE 3. Effect of treatment on development of storage decay. (Expressed in percent of fruit decayed.)

TREATMENT	FRUITS IN SAMPLE	DAYS AFTER ARRIVAL						REMARKS
		0	3	6	9	12	Average	
HW (44° F.*) 120°–118° F./20 min.	73	0	0	0	0	6.8	1.4	all normal
Control (44° F.*)	73	1.4	8.3	33.3	36.4	64.3	28.7	all normal
HW (55° F.*) 120°–118° F./20 min.	93	0	0	1.1	1.1	28.6	6.2	all normal
Control (55° F.*)	97	21.6	13.2	45.4	58.3	46.7	37.0	all normal

Required difference between treatment means: 5.7 for P=5%
120 for P=1%

*Shipping temperature.

TABLE 4. Effect of treatment on development of storage decay. (Expressed in percent of fruit decayed.)

TREATMENT	FRUITS IN SAMPLE	DAYS AFTER ARRIVAL								REMARKS
		0	1	2	3	4	5	6	Average	
Control........	140	10.7	5.6	9.3	18.7	20.7	15.9	37.9	17.0	all normal
HW 120°–118° F./20 min....	140	0	0	0	0.7	0	0.7	0.7	0.3	all normal
VH...........	140	0	0.7	0	3.6	1.5	0	10.6	2.3	6 scalded, sampled fruits flat tasting, 15 post ripe
Wax A........	56	1.8	1.8	3.7	13.5	0	2.2	36.4	8.5	blotchy coloring, otherwise normal
Wax B........	56	7.1	11.5	10.9	12.2	19.4	24.1	45.4	18.6	blotchy coloring, otherwise normal

Required difference between treatment means: 2.2 for P=5%
4.3 for P=1%

they were shipped to San Francisco. Shipping temperature at 44° F. Arrived in San Francisco, May 19. Average fruit temperatures after arrival, 54°–55° F. in the morning and 59°–60° F. in the afternoon. (See table 5.)

With the exception of the hot water treatment in Lot 2 of Shipment 3, fruits treated with short vapor-heat, vapor-heat, or hot water did not develop storage decay during transit (see arrival percentages, tables 1–5). Control fruits showed considerable percentages decayed in transit and comparatively higher rates of decay than heat treated (SVH, VH, HW) fruits during the storage period after arrival in San Francisco (tables 1–5).

In shipments 3 and 4 (tables 3 and 4), significantly higher percentages decayed during the later periods at room storage, while in Shipment 2 (table 2) the highest percent decayed during the first two days at room storage. However, the general tendency in both treated and control fruits was toward higher percentages after longer periods of storage than after shorter periods (tables 1–5).

The treatment using Dowicide A with Johnson's wax had less decay than the controls but was not as effective as the hot water or vapor-heat treatments.

TABLE 5. Effect of treatment on development of storage decay. (Expressed in percent of fruit decayed.)

TREATMENT	FRUITS IN SAMPLE	DAYS AFTER ARRIVAL									REMARKS
		0	1	2	3	4	5	6	7	Average	
Control............	38	21.0	13.3	30.8	43.8	11.1	25.0	33.3	50.0	28.5	normal
HW 120°–119° F./20 min........	30	0	0	0	0	0	0	3.3	3.4	0.8	normal

Required difference between treatment means: 13.5 for P=5%
25.0 for P=1%

The treatment using Brog-Dex wax with Dowicide A showed no difference from the controls in percent decayed (table 4).

Control fruits shipped at 44° F. had less decay than those shipped at 55° F. (table 3), especially during the transit period. The hot water treated fruits shipped at 44° F. and 55° F. did not show much difference during transit nor for nine days after arrival; but by the 12th day after arrival, hot water treated fruits shipped at 55° F. showed approximately four times as much decay as those shipped at 44° F.

The types of heat injury observed in the short vapor-heat and vapor-heat treatments ranged from slight to severe forms of scalding, losses of flavor, and hard spots in the flesh. The severe types of heat injury were observed only in the vapor-heat treatment of Lot 2 of Shipment 3.

Waxed fruits showed uneven color development, with blotchy patterns on the fruit surface. These fruits also had an artificial gloss which marred their general appearance.

Storage decay observed in shipments 1–5 was caused primarily by the anthracnose organism. The decay lesion started as a tiny, light brown spot, then developed rapidly, covering a circular area approximately ½–1 inch in diameter. This decay also penetrated deeply into the flesh of the fruit, and the infected portions formed cones or hemispheres of discolored and broken-down tissues in the fruit. Decay lesions occurring on the stem end (stem-end rots) usually started as tiny spots in the circular groove around the fruit stem and spread rapidly outward to the basal ridge and the sides of the fruit.

Some *Rhizopus* and blue mold growths were observed on the bruised surfaces of ripe fruits that had been damaged in transit; these organisms were also found to be secondary invaders of tissue already decayed by anthracnose.

Papayas shipped from Hilo had, in addition to anthracnose decay, many minute lesions caused by *Cercospora sp.** Table 6 shows the minimum and maximum numbers of these lesions observed in the controls and the hot-water treated fruits. These lesions seemed to be either raised conical spots, very light to dark brown, or black sunken spots with wrinkled edges. These lesions do not penetrate deeply into the flesh as the anthracnose lesions, and for this

TABLE 6. Effect of hot water on Cercospora rot of Hilo papayas. (Rot lesion counts made on the 7th day after arrival.)

TREATMENT	FRUITS IN SAMPLE	NUMBER OF LESIONS ON FRUIT		TOTAL LESIONS IN SAMPLE	AVERAGE PER FRUIT
		Min.	Max.		
HW 120°–119° F./20 min.	30	2	115	1044	35
Control	38	5	120	1588	42

Differences between treatments not significant.

* Organisms found on similar lesions on Hilo fruits were identified as *Cercospora sp.* by Dr. Harry Murakishi, University of Hawaii department of plant pathology.

reason this type of decay damages only the marketable appearance of fruits.

Papayas shipped from Oahu were generally free from *Cercospora* decay, and a few fruits showing this decay were not affected to an extent considered serious.

Table 7 shows cumulative percentages of decay not readily apparent in tables 1–5. From this table it can be shown that control fruits averaged approximately 72 percent decay by the 6th day and 92 percent decay by the 12th day after arrival, while the heat-treated fruits (VH, SVH, and HW treatments) averaged approximately 12 percent and 38 percent for the same periods. Table 7 also shows that as the storage time is extended from 6 days to 12 days the differences between the treated and controls are considerably decreased.

When the decay lesions were classified according to their location on the fruit surface, significantly greater numbers of these lesions were found to occur on the stem end than on the other parts. Table 8, which gives the distribution of stem-end rots and side rots in the test shipments, shows that in Shipment 1 the hot water and short vapor-heat treatments did not control side rots, and that heat treatments in general showed greater reduction in stem-end rots than inside rots.

Table 9 shows the distribution of fruits decayed at various stages of ripeness. This table shows that the heat treated fruits were usually free from decay until the ripe or nearly ripe stages, while control fruits decayed at all stages of ripeness. Table 10 shows the average proportions of control fruits in various stages of ripeness, and the theoretical numbers of decayed fruits expected on the assumption of equal probabilities of decay for all stages of ripeness. Chi-square tests show that this assumption is valid for control fruits in most of the test shipments. As the proportions in various stages of ripeness for treated fruits did not differ significantly from the controls, the proportions listed for controls in table 10 can also be taken as typical of treated fruits in each test shipment.

No significant differences were found between control and heat treated fruits in the percentages for color and ripeness during transit and after arrival. Some differences noted between controls and treated fruits in each shipment were slight and not consistent. In Lot 1 of Shipment 1 the controls had higher percentages of color and ripeness than the hot water treated fruits, but in Lot 2 of Shipment 1 the hot water treated fruits had higher percentages of color and ripeness. In shipments 2 and 3 the heat treated fruits had higher percentages of color and ripeness than the controls, while in Shipment 4 the controls had higher percentages than the heat treated fruits. The waxed fruits had lower percentages of color and ripeness than the heat treated or control fruits.

Large differences in color development and percentage of ripeness were found between shipments having different pre-shipment storage temperatures. Fruits stored at room temperatures before shipment had higher percentages of color and ripeness than those stored cold before shipment. Table 11 shows the average percentages and color for each shipment.

TABLE 7. Effect of treatment on the cumulative percentages of fruits decayed during transit and after arrival at room temperatures.

TREATMENT	FRUITS IN SAMPLE	DURING TRANSIT	DAYS AFTER ARRIVAL										
			1	2	3	4	5	6	7	8	9	10	12
Ship. 1, Lot 1													
HW 115° F./20 min..	50	0		2.0		10.0		20.0		40.0		40.0	48.0
SVH........	50	0		8.0		12.0		26.0		42.0		46.0	46.0
Control......	50	26.0		52.0		64.0		70.0		82.0		90.0	98.0
Ship. 1, Lot 2													
HW 115° F./20 min..	50	0		2.0		6.0		14.0		44.0		50.0	60.0
Control......	50	24.0		46.0		68.0		84.0		90.0		92.0	92.0
Ship. 2													
SVH........	80	0		6.2		8.7		13.7					
HW 120° F./20 min..	79	0		8.8		15.2		21.5					
Control......	55	14.5		65.4		69.1		80.0					
Ship. 3													
HW 120°–118° F./20 min. shipped at 44° F......	73	0			0			0			0		6.8
Control shipped at 44° F......	73	1.4			9.6			41.1			63.0		87.7
HW 120°–118° F./20 min. shipped at 55° F......	93	0			0			1.1			2.1		30.1
Control shipped at 55° F......	97	21.6			32.0			62.9			84.5		91.8
Ship. 4													
Control......	140	10.7	15.7	23.6	37.8	50.7	58.6	73.6					
HW 120°–118° F./20 min..	140	0	0	0	0.7	0.7	1.4	2.1					
VH..........	140	0	0.7	0.7	4.3	5.7	5.7	15.0					
Wax A.......	56	1.8	3.6	7.1	19.6	19.6	21.4	50.0					
Wax B.......	56	7.1	17.8	26.8	35.7	48.2	60.7	78.6					
Ship. 5													
Control......	38	21.1	31.6	52.6	71.1	73.7	78.7	84.2	89.5				
HW 120°–119° F./20 min..	30	0	0	0	0	0	0	3.0	6.0				

DISCUSSION OF RESULTS

The hot water, short vapor-heat, and vapor-heat treatments were equally effective in reducing storage losses of papayas due to anthracnose. The hot water treatment, however, must be considered a more desirable means of controlling anthracnose storage decay than either short vapor-heat or vapor-

TABLE 8. Effect of treatment on the development of stem-end and side rots.

TREATMENT	TOTAL FRUITS DECAYED	TOTAL DECAY LESIONS	TOTAL STEM-END ROTS	TOTAL SIDE ROTS
Ship. 1, Lot 1				
HW	24	34	22	12
SVH	23	32	17	15
Control	49	60	48	12
Ship. 1, Lot 2				
HW	30	35	22	13
Control	46	56	45	11
Ship. 2				
SVH	11	13	11	2
HW	17	17	17	0
Control	44	45	43	2
Ship. 3, Lot 1				
HW (44° F.*)	5	6	4	2
Control (44° F.*)	64	70	57	13
HW (55° F.*)	28	28	23	5
Control (55° F.*)	89	92	88	4
Ship. 3, Lot 2				
VH†				
HW (55° F.*)	17	17	16	1
Ship. 4				
HW	3	4	3	1
VH	22	22	16	6
Control	104	106	92	14
Wax A	28	30	26	4
Wax B	44	45	41	4
Ship. 5				
HW	2	2	1	1
Control	34	44	33	11
TOTAL	684	758	625	133

*Shipping temperature.
†Severely scalded from treatment, discarded.

heat: (1) The hot water method requires less time than vapor-heat treatments, and (2) it is not injurious to fruit quality.

Past findings from laboratory experiments have shown that the short vapor-heat and especially the vapor-heat treatment usually cause heat injury. Test shipment results confirm these findings. There seems to be no adequate selective process by which heat damaged fruits could be eliminated from the commercial pack because most heat injury occurs internally and is evident only when fruits are cut open. Fruits having severe forms of heat injury, such as the development of off-odors, off-flavors, or extensive areas of hard spots, do not necessarily show external symptoms, such as scalding. Severely scalded fruits presumably could be discarded immediately after the vapor-heat treatment or during the packing operation, but fruits having slight to mild forms

TABLE 9. Effect of treatment on the frequency of fruits decayed at various stages of ripeness.

TREATMENT	MATURE GREEN	COLOR TURNING	¼ RIPE	½ RIPE	¾ RIPE	RIPE	POST RIPE
Ship. 1, Lot 1							
HW	0	1	0	4	4	15	0
SVH	1	0	0	1	0	21	0
Control	10	1	9	13	6	10	0
Ship. 1, Lot 2							
HW	0	0	0	0	0	30	0
Control	12	0	2	10	5	17	0
Ship. 2							
SVH	0	0	0	1	1	9	0
HW	0	0	1	0	2	13	0
Control	2	2	5	10	6	19	0
Ship. 3, Lot 1							
HW (44° F.*)	0	0	0	0	0	5	0
Control (44° F.*)	0	7	2	4	5	45	0
HW (55° F.*)	0	0	0	0	0	28	0
Control (55° F.*)	0	15	2	4	1	67	0
Ship. 3, Lot 2							
HW	0	0	0	0	0	17	0
Ship. 4							
Control	0	2	1	6	11	84	0
HW	0	0	0	0	0	3	0
VH	0	0	0	0	2	11	9
Wax A	0	4	1	0	2	21	0
Wax B	0	7	2	5	6	24	0
TOTAL	25	39	25	57	51	440	9

*Shipping temperature.

of scald show this injury only after a period of storage or during the ripening period.

Dipping papayas in wax emulsions containing Dowicide A does not seem to be an efficient means of controlling storage decay. Past laboratory experiments using fungicides (*1*, *2*) have given inconsistent results and have been shown to be less effective than hot water in controlling storage decay. Also, waxing papayas in the mature green or color-turning stages produced blotchy coloring of papayas. Although blotchy coloring observed in the test shipments was not as pronounced as that observed on some waxed fruits in laboratory tests, the test shipment results generally confirm past experiences on blotchy coloring of waxed papayas.

Cercospora decay does not seem to be suppressed by the hot water treatment. Laboratory tests using hot water and vapor-heat treatments have shown also that this type of decay is not significantly reduced by heat treatments. The results of Shipment 5, using hot water on Hilo papayas, confirm the findings of previous laboratory tests.

TABLE 10. Relationship between stages of ripeness and frequency of storage decay in untreated fruits. (Chi-square test based on assumption of equal probabilities of decay in all stages of ripeness.)

SOURCE	STAGE OF RIPENESS	AVERAGE PROPORTION OF FRUITS IN SAMPLE	NUMBER OF DECAYED FRUITS FOUND	NUMBER OF DECAYED FRUITS EXPECTED
Ship. 1, Lot 1, Controls	mature green	.24	10	12
	color turning	.02	1	1
	¼ ripe	.14	9	7
	½ ripe	.16	13	8
	¾ ripe	.12	6	6
	ripe	.32	10	15
Chi-square value = 2.844; no significant departure from expected.				
Ship. 1, Lot 2, Controls	mature green	.26	12	12
	color turning	.02	0	1
	¼ ripe	.06	2	3
	½ ripe	.10	10	5
	¾ ripe	.12	5	5
	ripe	.44	17	20
Chi-square value = 6.783; no significant departure from expected.				
Ship. 2, Controls	mature green	.18	2	8
	color turning	.06	2	2
	¼ ripe	.11	5	5
	½ ripe	.18	10	8
	¾ ripe	.11	6	5
	ripe	.36	19	16
Chi-square value = 5.762; no significant departure from expected.				
Ship. 3, Controls . . . . . . (shipped at 44° F.)	color turning	.25	7	16
	¼ ripe	.05	2	3
	½ ripe	.07	4	4
	¾ ripe	.08	5	5
	ripe	.55	45	35
Chi-square value = 8.253; no significant departure from expected.				
Ship. 3, Controls . . . . . . (shipped at 55° F.)	color turning	.13	15	11
	¼ ripe	.03	2	3
	½ ripe	.03	4	3
	¾ ripe	.01	1	1
	ripe	.80	67	71
Chi-square value = 2.346; no significant departure from expected.				
Ship. 4, Controls	color turning	.10	2	11
	¼ ripe	.02	1	2
	½ ripe	.06	6	6
	¾ ripe	.06	11	6
	ripe	.76	84	79
Chi-square value = 14.878; significant departure from expected.				

TABLE 11. Effect of pre-shipment storage temperatures on coloring and ripening of papayas.

SOURCE	PRE-SHIPMENT STORAGE TEMPERATURE	SHIPPING TEMPER-ATURE	AT ARRIVAL		AT END OF STORAGE PERIOD	
			color	ripe	color	ripe
			%	%	%	%
Ship. 1, Lot 1	45° F., 36 hrs.	50° F.	13.8	30.2	45.8	71.2
Ship. 1, Lot 2	45° F., 36 hrs.	50° F.	20.0	40.2	55.2	92.0
Ship. 2	45° F., 36 hrs.	47° F.	30.8	44.4	52.2	74.2
Ship. 3, Lot 1	70°–80° F., 24 hrs.	44° F.	36.6	51.6	65.8	89.6
	70°–80° F., 24 hrs.	55° F.	62.8	78.0	85.0	94.8
Ship. 3, Lot 2	70°–80° F., 48 hrs.	55° F.	75.0	84.2	80.3	94.7
Ship. 4						
Waxed fruits	70°–80° F., 24 hrs.	47° F.	61.2	70.0	61.2	73.6
Other treat.	70°–80° F., 24 hrs.	47° F.	72.2	76.2	72.6	81.7
Ship. 5*	44° F., 72 hrs.	44° F.	50.0	25.2	95.0	52.2

*The strain of papayas shipped from Hilo showed approximately 50 percent color before shipment.

Akamine and Arisumi pointed out (*1*) that anthracnose storage decay is the major cause of loss of papayas shipped from Hawaii to the mainland United States. They also claimed that this decay occurred predominantly on the stem end of the fruit and that these fruits were more likely to decay after long periods of storage at room temperatures. The results of the test shipments confirm their observations made in laboratory tests (*1*, *2*).

It should be noted that decay lesions are likely to develop in untreated fruits at any stage of ripeness after arrival on the market, and for this reason, shipping fruits in the earlier stages of ripeness cannot be considered to be a good preventive measure against storage decay. Since green fruits must be ripened before they can be sold, the chances of decay are increased because of the extended storage period.

Mature green to color-turning fruits can be colored and ripened to a more desirable marketable quality by storing them in sealed cartons for 24–36 hours at room temperatures (70°–80° F.) before shipment. This practice is considered essential for papayas shipped during the winter season; little or no improvement in coloring and ripening can be expected during the transit period at temperatures from 44°–55° F. or after arrival in San Francisco where room temperatures are usually not higher than 55°–60° F. Fruits arriving in San Francisco in the mature green or color-turning stages usually remain in that stage of ripeness, or they ripen only to the ¼–½-ripe stages in the 1–2 week storage periods at room temperatures. Fruits arriving in the ½–¾-ripe stages, the optimum stages of ripeness at arrival, usually ripen within a week. Fruits arriving in the ripe stage generally remain edible for 1–2 weeks after arrival.

From the results obtained in the test shipments the following practices are suggested for shipping papayas during the winter season:

1. Treat papayas with hot water at 120° F. for 20 minutes prior to the EDB treatment.

2. Ripen mature green or color-turning fruits beyond the ¼-ripe stage at room temperatures (70°–80° F.) before shipment.
3. Ship fruits in ¼-ripe to ripe stages at 44° F.

SUMMARY

The results of the test shipments confirm observations of previous laboratory tests conducted under simulated shipping conditions (*1*, *2*, *6*). These results are summarized as follows:

1. A major cause of storage losses in papayas shipped to the mainland market is due to anthracnose storage decay.

2. This storage decay occurs predominantly on the stem end of the fruit.

3. Untreated papayas become susceptible to storage decay as soon as they begin to ripen, and they are likely to decay at all stages of ripeness.

4. Papayas shipped at 44° F. have less storage decay than those shipped at 55° F.

5. Anthracnose storage decay of papayas can be reduced by treating papayas with hot water, short vapor-heat, or vapor heat.

6. The hot water treatment is considered better than either the short vapor-heat or vapor-heat treatments because it requires less time and does not injure fruit quality.

7. The hot water treatment does not control *Cercospora* decay of Hilo papayas.

8. To attain better marketable quality in winter, mature green and color-turning fruits can be ripened and colored by storing them in sealed shipping cartons at room temperatures (70°–80° F.) for 24–36 hours before shipment.

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